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Review

Converter for Voltage Source HVDC Links: Current Status and Future Challenges

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Abstract: This article discusses the current state of DC HVDC technology. The article describes the history of DC HVDC technology, starting with its early development as a voltage source, and then discusses the introduction of line-cutting into current designs. The article discusses control and coordination of transformers, as well as the need for a DC breaker to facilitate control of multiple plants. Recent developments in the design of DC circuit breakers are discussed. The importance of reliability is recognized, especially in relation to cables, and the issues surrounding cable design are explained. Ongoing and planned installations of VHF-VHF DC installations are described.

Keywords: DC; Voltage Converter; Cable Connection; High Voltage

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1. Introduction

1.1 Background

Despite the fact that DC power transmission was initially employed in the early design of utility power in the 1880s-1900s, AC has multiple benefits. These include the simple conversion of low voltage to higher voltage via AC transformers, the ease of using AC power breaks to stop the flow of faulty current via the AC nature of the waveform, and the general popularity of AC induction motors. As such, the majority of communications and distribution systems around the world are traditionally built with the AC in mind. However, high-voltage DC is still utilized in some instances where it has a technical and economic benefit, such as the asynchronous nature of its conductivity or the technical and economic benefits of long-range communication [1]...

1.2 Historical Development

Even at the beginning of the 20th century, links between direct current and alternating current continued to be used, for example the 125 kV, 20 MW Moutiers-Lyon link (230 km) which operated from 1906 to 1936 and used 8 DC generators connected in series [2]. In the UK, the 100 kV Wilsden-Ironbridge link was built in 1910 and spanned 22.5 km. However, it was not until a practical device for switching was found that high-voltage direct current came into common use. The first device to employ the mercury rectification principle, the mercury arc rectifier, initially had problems with back arcing. However, these issues were primarily addressed by Uno Lam in Sweden, who, in 1939, had devised a method to create a single valve system that would increase the return path voltage by providing a gradient [3]. This was followed by various experimental investigations in America, Germany, Russia, Switzerland, and Sweden.... Arguably the first modern commercial installations were built in the 1950s. Gotland Link 1 had 20 million watts of power and ran from Vaster Vik to Jene, with a length of 98 kilometers. Although it was built in 1954, it was not abandoned until 1986. In 1951, a 30-million-watt, 100 kilometer, +/-100 kV

power transmission line was also built from Moscow to Kas [4, 5]. The Gotland expansion project, which took place in 1970, was considered one of the first to utilize this method. The creation of mercury-based arcade mirrors was attempted for a long time, for example. mercury-based arcade rectifiers [6-8].

The process of achieving this involves first obtaining a basic understanding of the situation, then attempting to solve the problem, and finally reaching a conclusion. " The third step is to spend money on different companies and create a portfolio of investments that maximizes efficiency while minimizing risk [9]. They're in the middle of a transition, from the traditional method of manufacturing to a more modern approach that involves more production volume [10]. Currently, the most effective transition is between the PNE and the ACA, both of these have benefits associated with them." (CSC) or "linear" converters (LCC). Figure 1. Because of the frequent changes in voltage and the use of IGBTs instead of thyristors, as a result, the AC-DC system is employed in locations that require black start capabilities, or where space is limited and the cost is prohibitive, transmissions that have the greatest voltage across each IGBT as their goal is to modulate (or increase) the voltage.

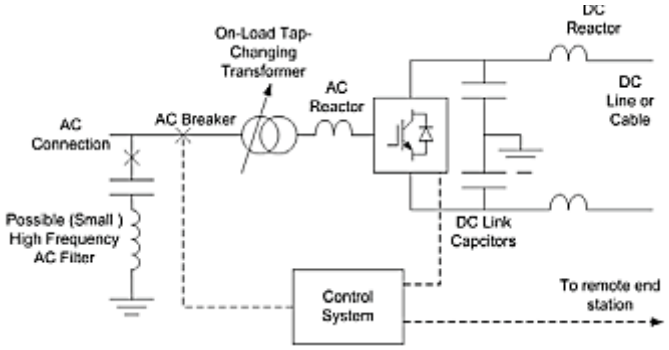

Figure 1 Converter Source: HVDC Sketch of Central Elements

ABB can have 3 versions of the new operating system [11]. NPC can be a parallel anti-parallel diode [12]. The diode can be +½Vdc, 0Vdc and -½Vdc. But I can't tell you that this doesn't mean that everything is fine. But even though ABB "PWM Optimizasiyası", ABB still uses "PWM Optimizasiyası" at least in the minimum installation...

Alstom's Grid and ABB have products similar to the MMC design. Many different topologies have been created with the general consensus

The evolution of the switch is briefly described in Table 1. The two-level cascade switch (CTL, ABB) uses a serial link for the power electronics in each of the submodules, and this reduces the number of submodules as the voltage on each of the DC capacitors increases [13].

Since the design of semiconductor switches is a compromise between quick cycling, low conduction loss, or high voltage blocking, there are additional benefits to lower switching frequencies [14]. This may promote a greater emphasis on reducing conduction losses and maximizing the voltage blocking of semiconductor switches, both of which are benefits of reducing the frequency of switching [15].

2. Materials and Methods

2.1 Key Issues

Constant high voltage procurement is a recently developed field that is rapidly growing [16]. The categorization of installations has evolved from several hundred megawatts to installations with a planned capacity of 1,000 megawatts or more in the last few years. However, there are several important concepts that should be considered in greater detail, specifically regarding some of the currently under development offshore networks that have multiple stations [17].

2.1 DC Circuit Breakers

Today's VSC-HVDC systems are 2-station installations that are direct Point-to-Point and have a clear fault detection mechanism that utilizes AC power; therefore, they do not need to have a DC power source like the 14. For systems with multiple stations, as illustrated in Figure 2, a fault is defined as the AC breakers being tripped, the DC is isolated from the entire DC network, quick-fix switches that are located in the AC power supply isolate the fault, the system is re-energized, and the process continues. This is time-consuming and does not follow the traditional approach to protection. As a result, DC breakers have been the subject of intense study. The difficulty here is that there is not a zero current and/or voltage like the AC breaker [18]. Therefore, breaking the current flow is more difficult. Several solutions have been proposed.

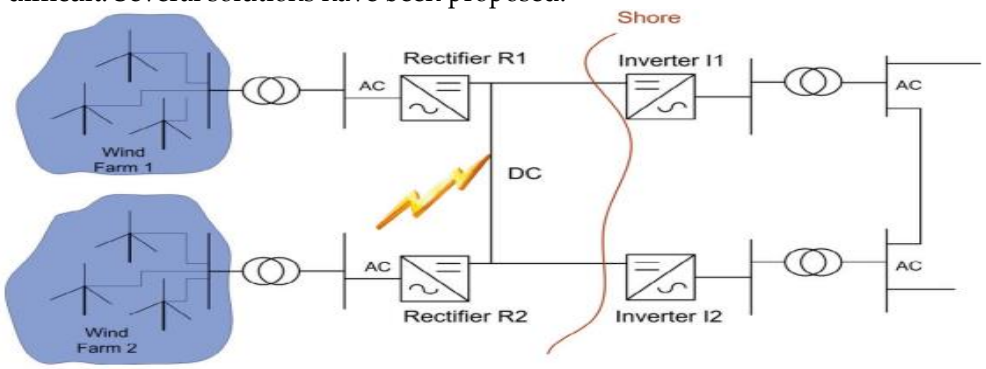

figure 2 DC Arrangement with seaward cable liability

2.2 Multi-terminal Control

The movie is about a man who, upon returning home, finds that his life's work is complete and that there is nothing more important [19-21]. The concept of few is derived from the idea of few, the concept of many is derived from the idea of many, and the concept of few is derived from the idea of many. Effectiveness studies [22, 23] and Oren in patient monitoring [24, 25]. Inquiry is the process of finding solutions to problems using scientific methods. These methods are then applied to problems of a similar nature. This is followed by a process of analyzing the results and making conclusions or adjustments. As is currently the case, the genetic code has a significant impact on the prevalence of genetic disorders [26].

The dual concerns of transformer compatibility and protection coordination are still important. It's expected that in the future, if large onshore or offshore networks are constructed, different manufacturers will have to connect their transformers to the same voltage. These machines must be effective. This compatibility must be maintained even when additional enhancements to software and hardware are expected. If the DC networks connect different AC networks with different levels of evolution, the significance of the connection must be considered, as there are different methods of operation. Protection methods and theories should be in agreement and supplementary. Some long distance HVDC projects that are multi-faceted in nature are currently in debate, it's expected that the concerns of control and protection will become more significant as practical knowledge is gained. The practical experience of multi-station systems that are multiple stations in depth is still modest. The Shin-Shinano substation in Tokyo was built by Toshiba, Hitachi, and Mitsubishi Electric as part of a joint venture with the Tokyo Electric Power Company. This cascaded multiple-station VSC-HVDC multiple-station substation employs multiple-station substations that use multiple-station substations. The low capacity (53 MVA per transformer) of the first transformer, the single location of the three transformers, and the resulting simple control schemes all contribute to the limited experience of this installation being able to be applied to multiple stations in DC systems all over the world. However, this is the only recent multiple station VLF-HF DC installation. Hydro-Quebec's installation in 1929 [27] and SACOI's scheme in 1929 [27] In Italy, the LCC method is used. Both scenarios can apply to multiple stations of the system

2.3 Reliability

The capacity of any transmission method to be accessible is of paramount importance to the determination if the method is technologically and commercially viable. The UK alone will create over 25 VHF, HF and UHF links that will connect offshore wind farms. Exactly determining the length of these connections is of great importance [28]...

The data regarding reliability obtained from VLF, VHF, VLF, and VHF schemes is beneficial for estimating the future probability of availability of VLF, VHF, VLF and VHF schemes with multiple unit converters. Additionally, studying the availability data will facilitate the identification of the primary components that influence the scheme's availability and will develop mitigation strategies. To this point, the owners of VLF, LF, VLF and VLF schemes have chosen not to participate of the global VLF., LF and VLF reliability study. However, some information on the reliability of the Mura link project and the Cross Sound cable project has been released in the Cigre article [29]

Seger's survey questions as well as academic publications were employed to conduct the availability analysis without having to provide any specific VSC-HVDC data regarding reliability [30]...

Cable Modelling The complex design of a VSC-HVDC cable has multiple components, see Figure 3 [31]. Several different cable types that are commercially viable can be employed to represent the behavior of this type of cable. The following describes the common types of cable that are available in PSCAD and SimPower Systems:

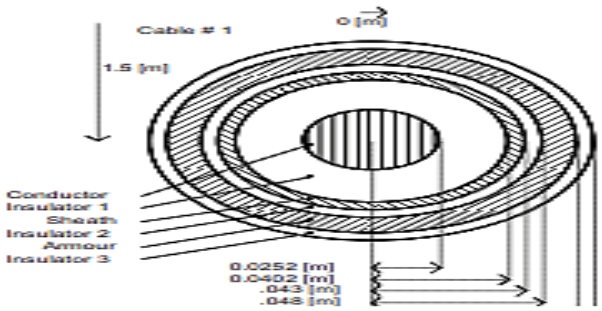

Figure 3 Structure of Cable

PI-section model –

This model combines the cable's flexibility, R, cable's capacity for capacitance, C, and the cable's inductance, L, all of which are typically employed to describe situations that are consistent over time and short distances. As the frequency of the interest or the length of the cable increases, the number of parts needed to describe the cable's propagation characteristics increases. This increases the cost of computational resources. This style of modeling is common in both PSCAD and SimPower [32].

Bergeron model –

The Bergeron model is derived from traveling wave theory and promotes the concept that the parameters of cable are spread across its length. The resistance of the cable is considered as a single entity, divided into three equal parts, half of which is located at the center, and a quarter of which is located at each end. This model is similar to the PI model but lacks the dependence on frequency of the cable attributes, this is why it's primarily dependent on frequency. PSCAD and SimPower Systems share a similar framework derived from the Bergeron model [33]....

Frequency-dependent Models –

The process of creating this piece involved first addressing the issue of how to create a symbol of unity while also acknowledging the diversity of the country. As a result, the piece comprised of a series of drawings that represented the various aspects of unity in a way that represented the diversity of the country. Two of the four scenarios have a positive outcome: the first is based on the situation, the second is based on the same concept, but with a different approach. Distinction between the two is based on the number of employees or projects they manage, the latter of which is often smaller in scale. The small

princess of the man who lay into the back of the planet, the wind caused a small rock to collide with the moon of the planet's mouth. The resulting fission of the planet's core was the most precise and accurate of its kind. The concept of a subject that is observed, recorded, and studied is called a focus of attention. The specialized market is characterized by a focus on the subject of specialization. acquired through the investigation of a prototype for a high voltage direct current (HVDC) cable that is part of a standard cable set that is also used in communications and entertainment [34]...

4. Discussion

This article described the state of the art of HVDC technology for voltage source conversion at the present time. Key questions regarding multiple stations, protection, reliability, cable design and modeling have been addressed. This is a field that is rapidly growing and is likely to undergo significant changes over the next few years.

Conflicts of Interest: Declare conflicts of interest or state “The authors declare no conflict of interest.”

References

1. Mayordomo, I., et al., *An overview of technical challenges and advances of inductive wireless power transmission.* Proceedings of the IEEE, 2013. **101**(6): p. 1302-1311.
2. Schultz, T., *Identification and Improvement of HVDC Circuit Breaker Interruption Limits*. 2019, ETH Zurich.
3. MARSH, R., *Diesel-electric drives.* Transactions, 1939. **51**(1).
4. Bokhan, P.A., et al., *Frequency and energy characteristics of a Cu–Ne laser at different durations of the leading edge of the excitation pulse.* Quantum Electronics, 2019. **49**(8): p. 749.
5. Petin, V., et al., *X-ray source for irradiation of large-area objects.* Technical Physics, 2008. **53**: p. 776-782.
6. Røpke, I., *The early history of modern ecological economics.* Ecological economics, 2004. **50**(3-4): p. 293-314.
7. Moodie, J., et al., *Towards a territorially just climate transition—Assessing the swedish EU territorial just transition plan development process.* Sustainability, 2021. **13**(13): p. 7505.
8. Kander, A., *Economic growth, energy consumption and CO2 emissions in Sweden 1800-2000.* 2002.
9. Palombo, C., *Eight steps to optimize your strategic assets.* IEEE Power and Energy Magazine, 2005. **3**(3): p. 46-54.
10. Ruhnka, J.C. and J.E. Young, *Some hypotheses about risk in venture capital investing.* Journal of business venturing, 1991. **6**(2): p. 115-133.
11. Robotics, A., *Operating manual robotstudio.* Västerås, Sweden, 2007.
12. Li, P.L., et al. *Experiences and results from initiating field defect prediction and product test prioritization efforts at ABB Inc*. in *Proceedings of the 28th international conference on Software engineering*. 2006.
13. Debnath, S., et al., *Models and Methods for Assessing the Value of HVDC and MVDC Technologies in Mondern Power Grids*. 2019, Oak Ridge National Lab.(ORNL), Oak Ridge, TN (United States).
14. Bryant, A., et al., *A fast loss and temperature simulation method for power converters, Part I: Electrothermal modeling and validation.* IEEE transactions on power electronics, 2011. **27**(1): p. 248-257.
15. Polom, T.A., B. Wang, and R.D. Lorenz, *Control of junction temperature and its rate of change at thermal boundaries via precise loss manipulation.* IEEE Transactions on Industry Applications, 2017. **53**(5): p. 4796-4806.
16. Mazzanti, G. and M. Marzinotto, *Extruded cables for high-voltage direct-current transmission: advances in research and development.* 2013.
17. De Sanctis, M., et al., *Satellite communications supporting internet of remote things.* IEEE Internet of Things Journal, 2015. **3**(1): p. 113-123.
18. Belda, N.A., C.A. Plet, and R.P.P. Smeets, *Analysis of faults in multiterminal HVDC grid for definition of test requirements of HVDC circuit breakers.* IEEE Transactions on Power Delivery, 2017. **33**(1): p. 403-411.
19. Foerst, R., et al., *Multiterminal operation of HVDC converter stations.* IEEE Transactions on Power Apparatus and Systems, 1969(7): p. 1042-1052.
20. Kübler-Ross, E. and D. Kessler, *On grief and grieving: Finding the meaning of grief through the five stages of loss*. 2014: Simon and Schuster.
21. Kunjufu, J., *The conspiracy to destroy Black boys.* Document Resume Ed 285 928 Ud 025, 1985. **682**: p. 20.
22. Lee, D., *Lattice simulations for few-and many-body systems.* Progress in Particle and Nuclear Physics, 2009. **63**(1): p. 117-154.
23. Mazzocchi, F., *Could Big Data be the end of theory in science? A few remarks on the epistemology of data-driven science.* EMBO reports, 2015. **16**(10): p. 1250-1255.
24. Xu, L. and L. Yao, *DC voltage control and power dispatch of a multi-terminal HVDC system for integrating large offshore wind farms.* IET renewable power generation, 2011. **5**(3): p. 223-233.

25. Liang, J., et al., *Operation and control of multiterminal HVDC transmission for offshore wind farms.* IEEE Transactions on Power Delivery, 2011. **26**(4): p. 2596-2604.
26. Gomis-Bellmunt, O., et al. *Multiterminal HVDC-VSC for offshore wind power integration*. in *2011 IEEE Power and Energy Society General Meeting*. 2011. IEEE.
27. Long, W.F., et al., *Application aspects of multiterminal DC power transmission.* 1990.
28. Khawaja, W., et al., *A survey of air-to-ground propagation channel modeling for unmanned aerial vehicles.* IEEE Communications Surveys & Tutorials, 2019. **21**(3): p. 2361-2391.
29. Dodds, S., *HVDC VSC (HVDC light) transmission-operating experiences.* CIGRE Session 2010, 2010.
30. Shen, L., et al. *A review on VSC-HVDC reliability modeling and evaluation techniques*. in *IOP Conference Series: Materials Science and Engineering*. 2017. IOP Publishing.
31. An, T., G. Tang, and W. Wang, *Research and application on multi-terminal and DC grids based on VSC-HVDC technology in China.* High Voltage, 2017. **2**(1): p. 1-10.
32. Tian, M., et al., *Design, modeling, and optimization of a coaxial cable-embedded flexible inductor for wearable applications.* IEEE Journal of Emerging and Selected Topics in Power Electronics, 2019. **7**(3): p. 1691-1702.
33. Elgamasy, M.M., et al., *Virtual difference voltage scheme for fault detection in VSC-HVDC transmission systems.* Journal of Modern Power Systems and Clean Energy, 2020. **8**(5): p. 991-1004.
34. Pless, N. and T. Maak, *Building an inclusive diversity culture: Principles, processes and practice.* Journal of business ethics, 2004. **54**: p. 129-147.